



US008178897B2

(12) **United States Patent**
Domanski et al.

(10) **Patent No.:** **US 8,178,897 B2**
(45) **Date of Patent:** **May 15, 2012**

(54) **SEMICONDUCTOR ESD DEVICE AND METHOD OF MAKING SAME**

(75) Inventors: **Krzysztof Domanski**, Munich (DE); **Cornelius Christian Russ**, Diedorf (DE); **Kai Esmark**, Neuried (DE)

(73) Assignee: **Infineon Technologies AG**, Neubiberg (DE)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **12/872,402**

(22) Filed: **Aug. 31, 2010**

(65) **Prior Publication Data**

US 2010/0321843 A1 Dec. 23, 2010

Related U.S. Application Data

(62) Division of application No. 12/138,208, filed on Jun. 12, 2008, now Pat. No. 7,800,128.

(51) **Int. Cl.**
H01L 29/66 (2006.01)

(52) **U.S. Cl.** . **257/173; 257/174; 257/362; 257/E29.181; 327/445; 327/460; 327/545**

(58) **Field of Classification Search** 257/173, 257/174, 362, E29.181; 327/445, 460, 545
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,574,618	A	11/1996	Croft
5,880,488	A	3/1999	Yu
6,055,143	A	4/2000	Yu
6,353,237	B1	3/2002	Yu
6,803,633	B2	10/2004	Mergens et al.

7,113,377	B2	9/2006	Salome et al.
7,205,611	B2	4/2007	Honjoh et al.
7,589,944	B2	9/2009	Mergens et al.
7,973,334	B2*	7/2011	Verleye et al. 257/173
2002/0041007	A1	4/2002	Russ
2004/0164356	A1	8/2004	Josef Mergens et al.
2006/0011939	A1	1/2006	Mohn et al.
2007/0002508	A1	1/2007	Vanysacker et al.
2007/0058307	A1	3/2007	Mergens et al.
2007/0236842	A1	10/2007	Choi
2008/0001168	A1	1/2008	Manna et al.
2008/0233686	A1*	9/2008	Lee et al. 438/133
2009/0166671	A1	7/2009	Hwang
2010/0044748	A1	2/2010	Lin et al.

(Continued)

OTHER PUBLICATIONS

Mergens, M. P. J., et al., "High Holding Current SCRs (HHI-SCR) for ESD Protection and Latch-up Immune IC Operation," *Microelectronics Reliability*, Jul. 2003, pp. 993-1000, vol. 43, Issue 7.

(Continued)

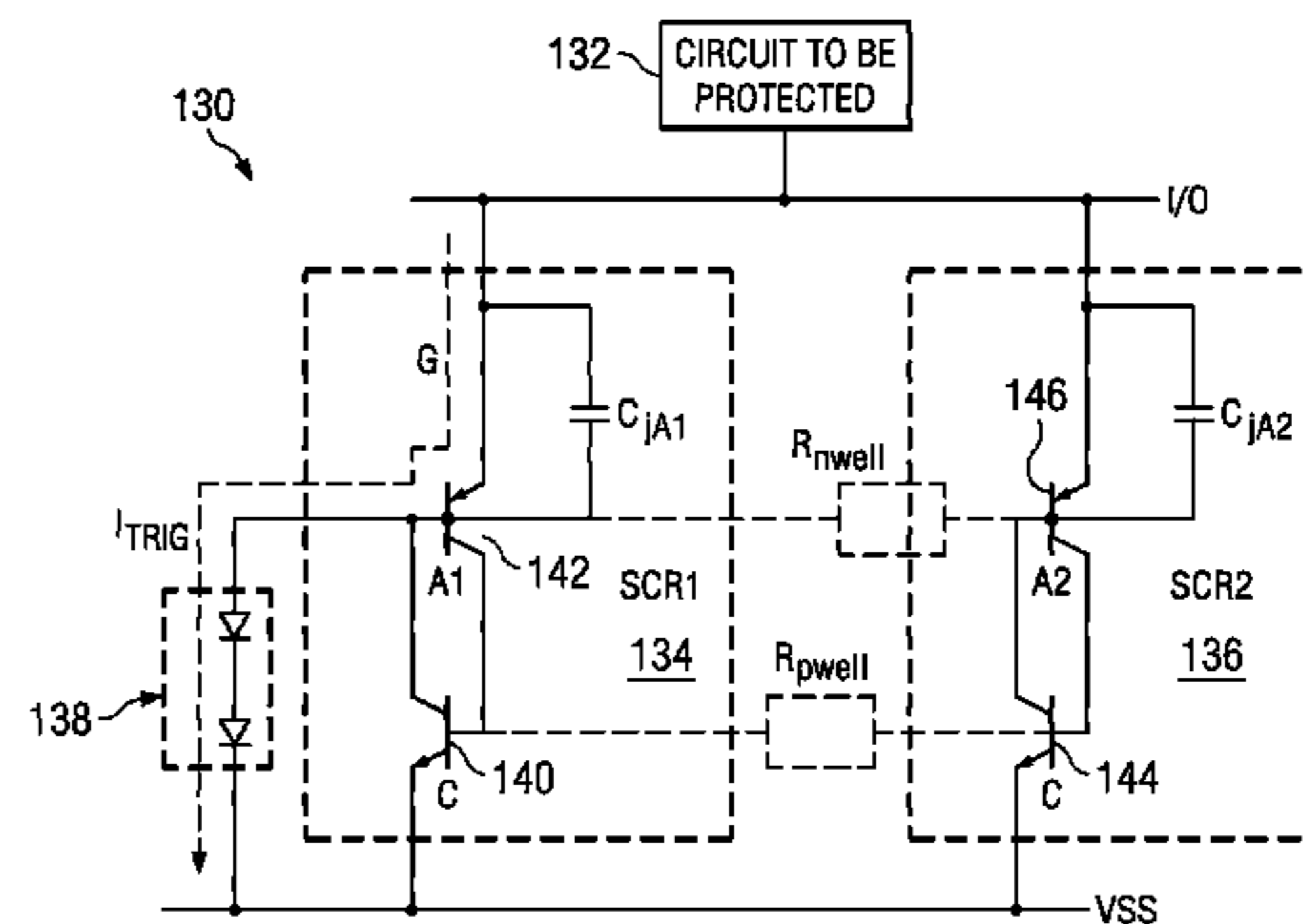
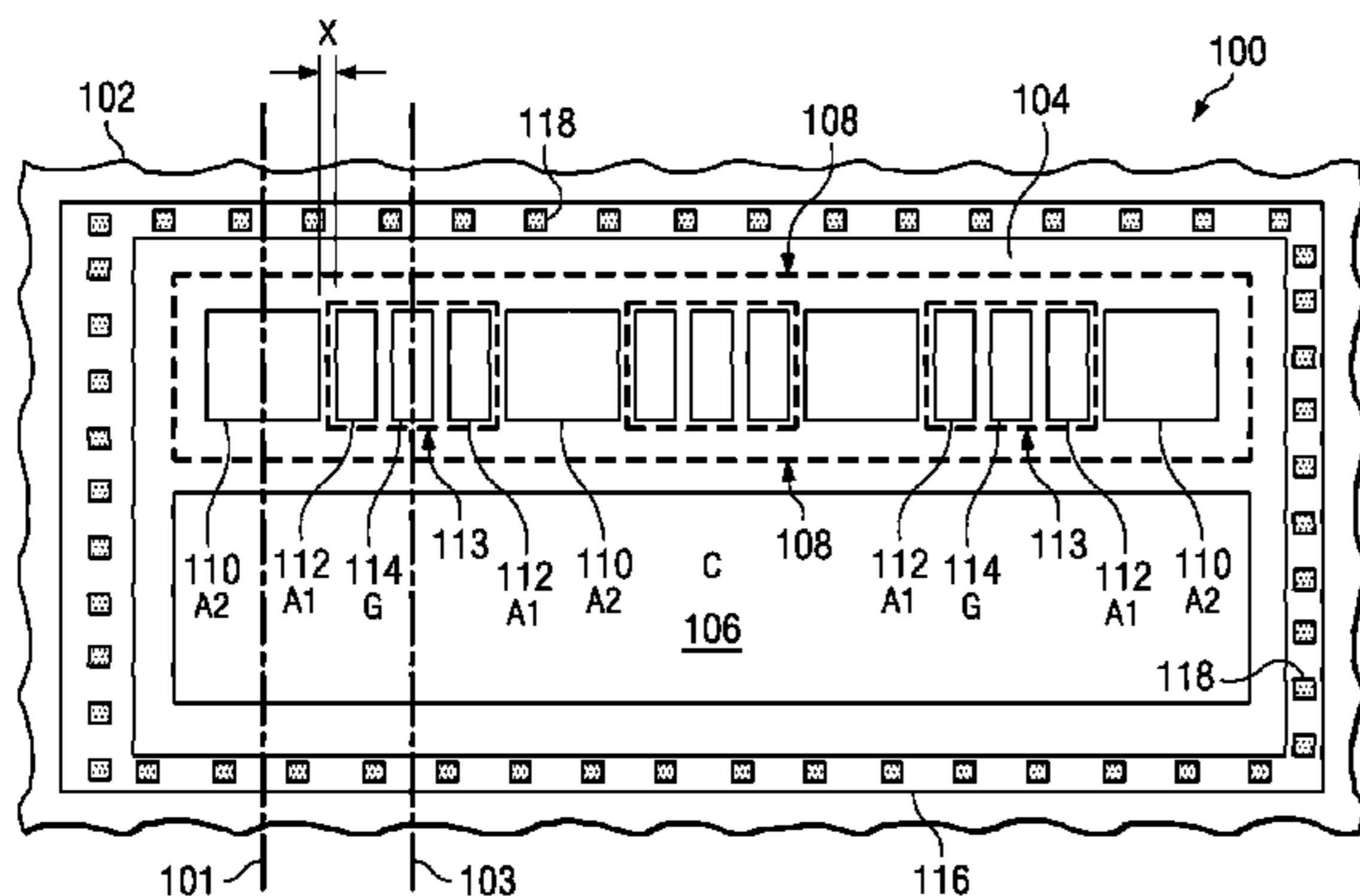
Primary Examiner — Ngan Ngo

(74) *Attorney, Agent, or Firm* — Slater & Matsil, L.L.P.

(57) **ABSTRACT**

A semiconductor device includes an SCR ESD device region disposed within a semiconductor body, and a plurality of first device regions of the first conductivity type disposed on a second device region of the second conductivity type, where the second conductivity type is opposite the first conductivity type. Also included is a plurality of third device regions having a sub-region of the first conductivity type and a sub-region of the second conductivity type disposed on the second device region. The first regions and second regions are distributed such that the third regions are not directly adjacent to each other. A fourth device region of the first conductivity type adjacent to the second device region and a fifth device region of the second conductivity type disposed within the fourth device region are also included.

10 Claims, 9 Drawing Sheets



U.S. PATENT DOCUMENTS

2011/0013326 A1* 1/2011 Ker et al. 361/56
2011/0147794 A1* 6/2011 Gauthier et al. 257/162

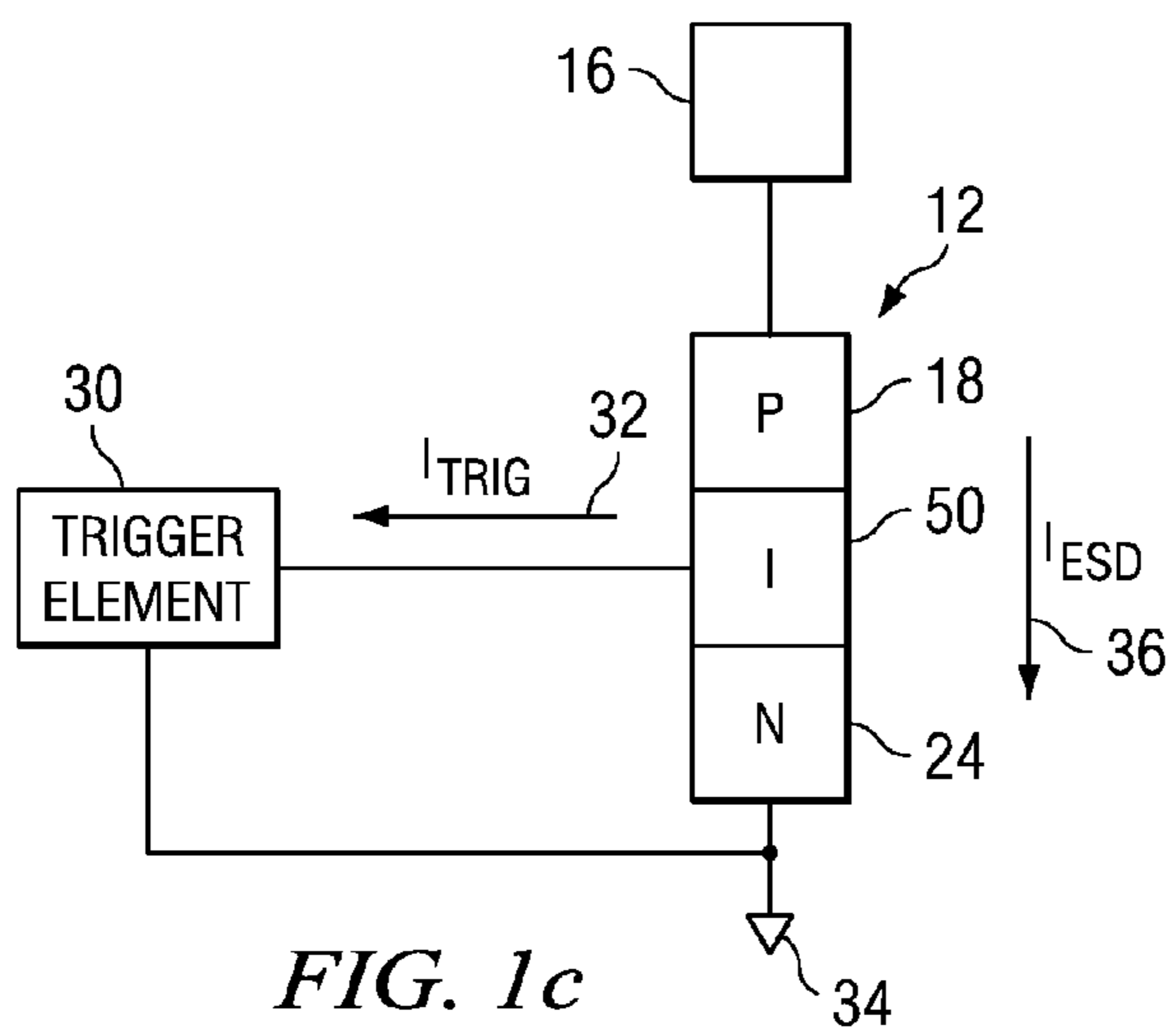
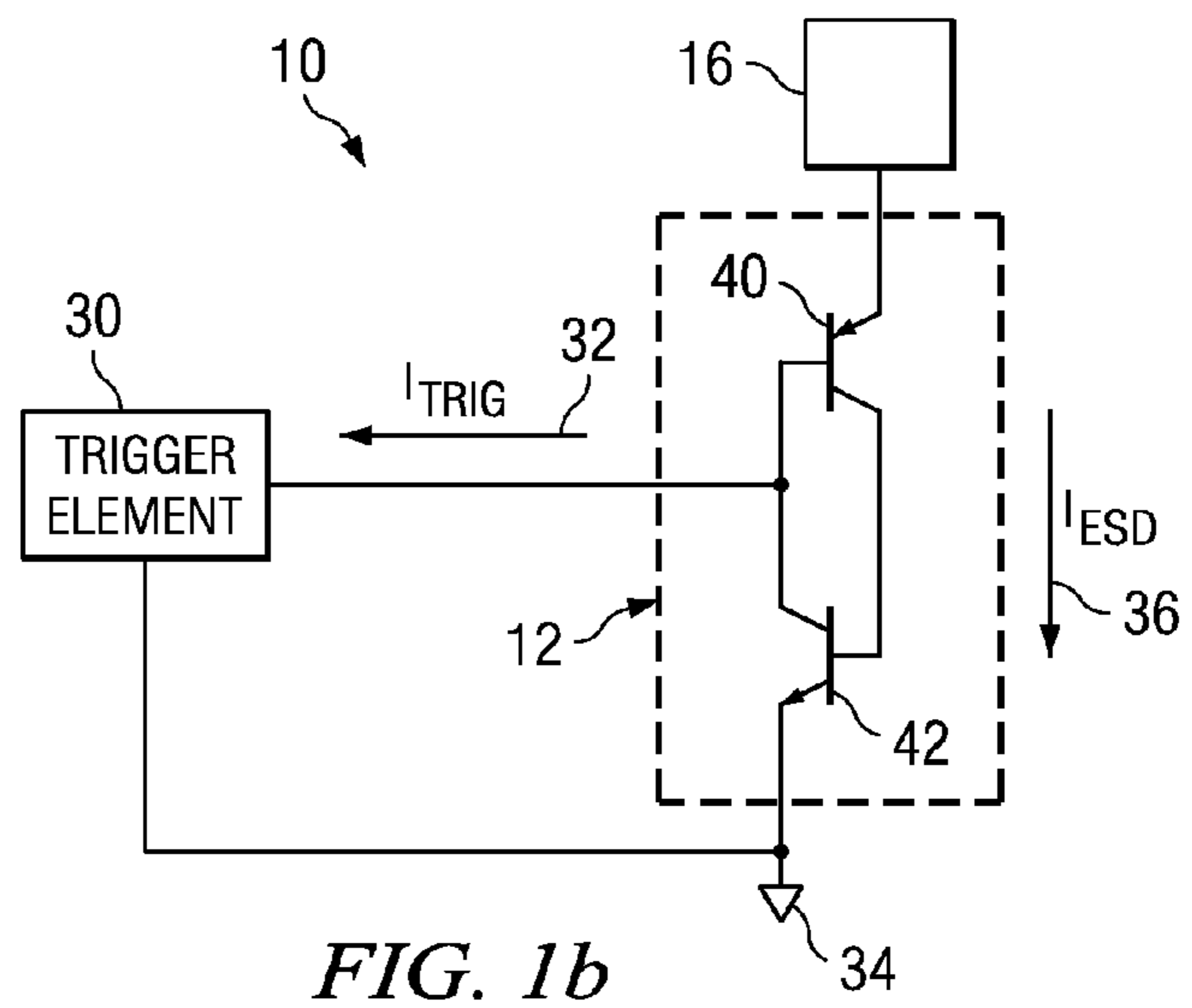
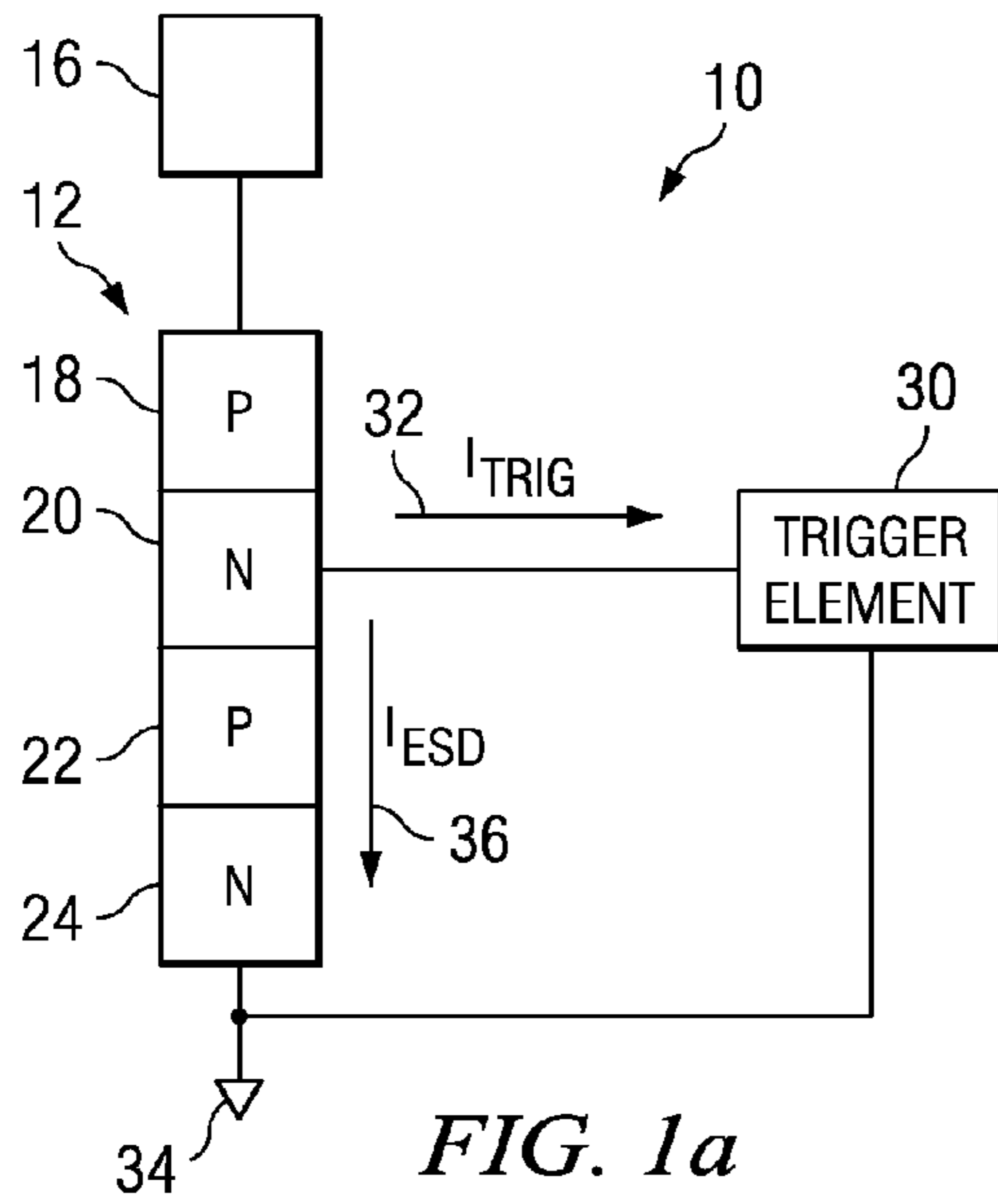
OTHER PUBLICATIONS

Litzenberger, M., et al., "Scanning Heterodyne Interferometer Setup for the Time-Resolved Thermal and Free-Carrier Mapping in Semiconductor Devices," IEEE Transactions on Instrumentation and Measurement, Dec. 2005, pp. 2438-2445, vol. 54, No. 6.

Pogany, D., et al., "Moving Current Filaments in ESD Protection Devices and Their Relation to Electrical Characteristics," IEEE International Reliability Physics Symposium Proceedings, Mar. 30-Apr. 4, 2003, pp. 241-248.

Caillard, B., et al., "STMSCR: A New Multit-Finger SCR-Based Protection Structure Against ESD," Electrical Overstress/Electrostatic Discharge Symposium, Sep. 21-25, 2003, 9 pages.

* cited by examiner



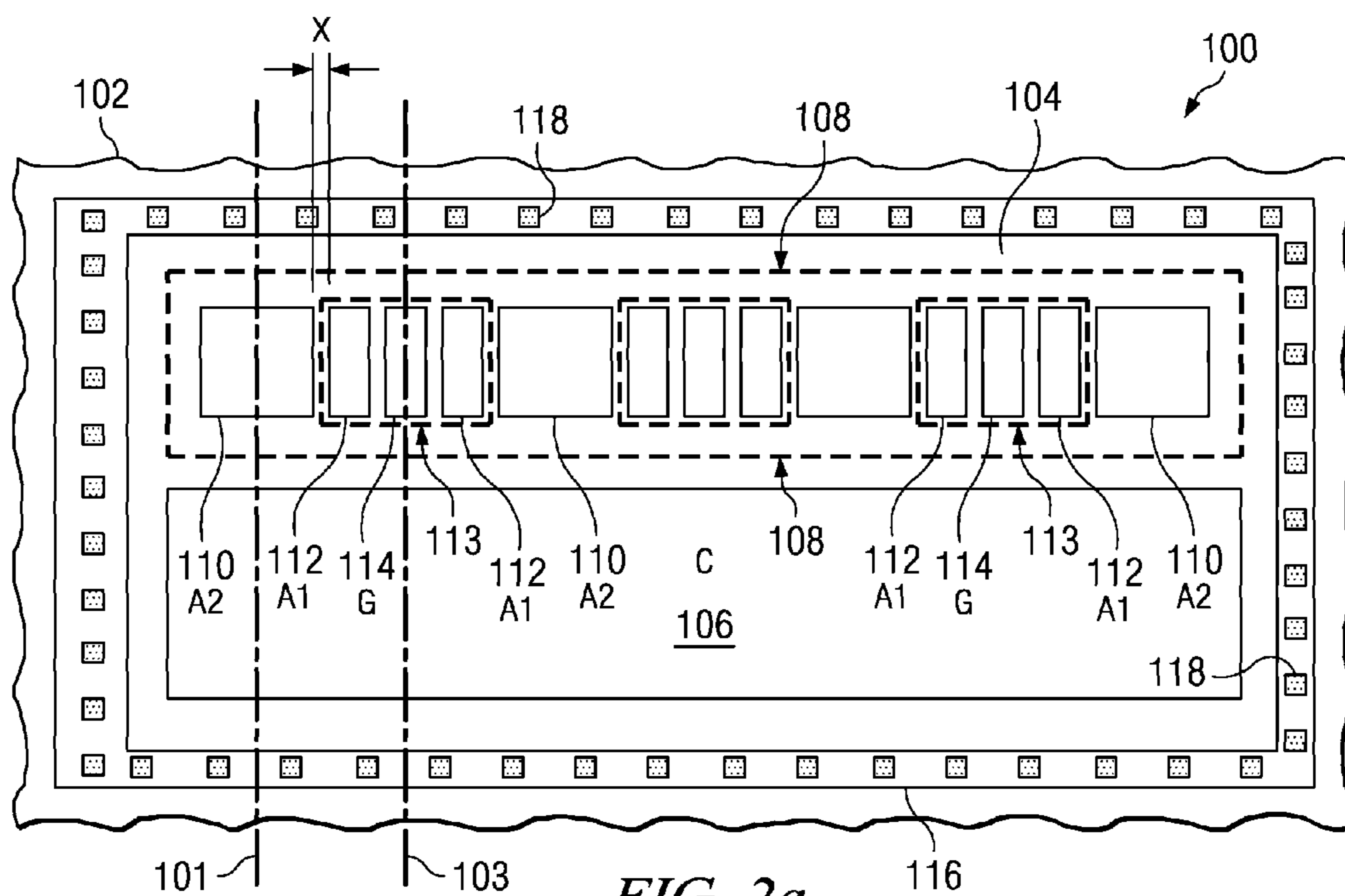


FIG. 2a

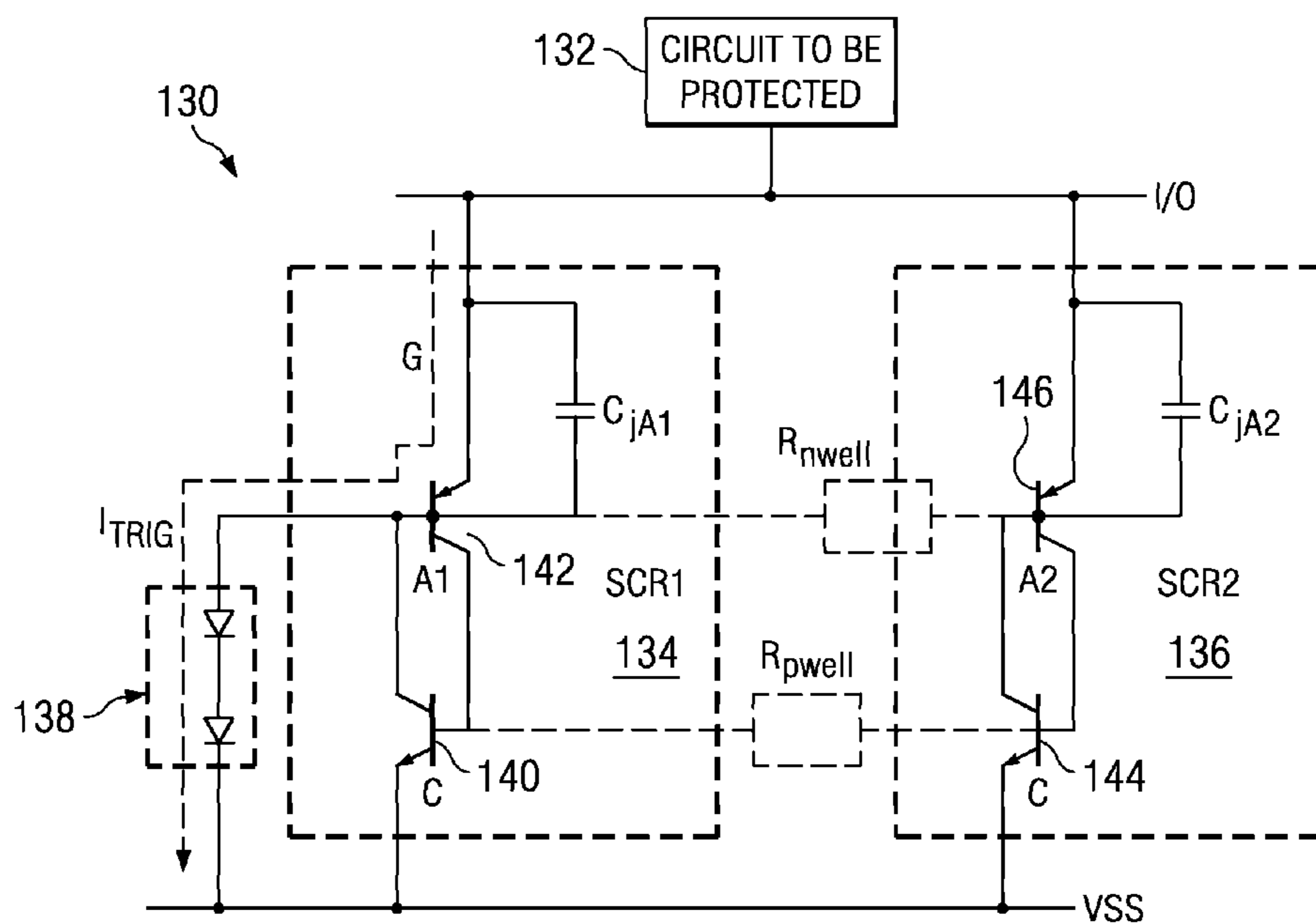


FIG. 2b

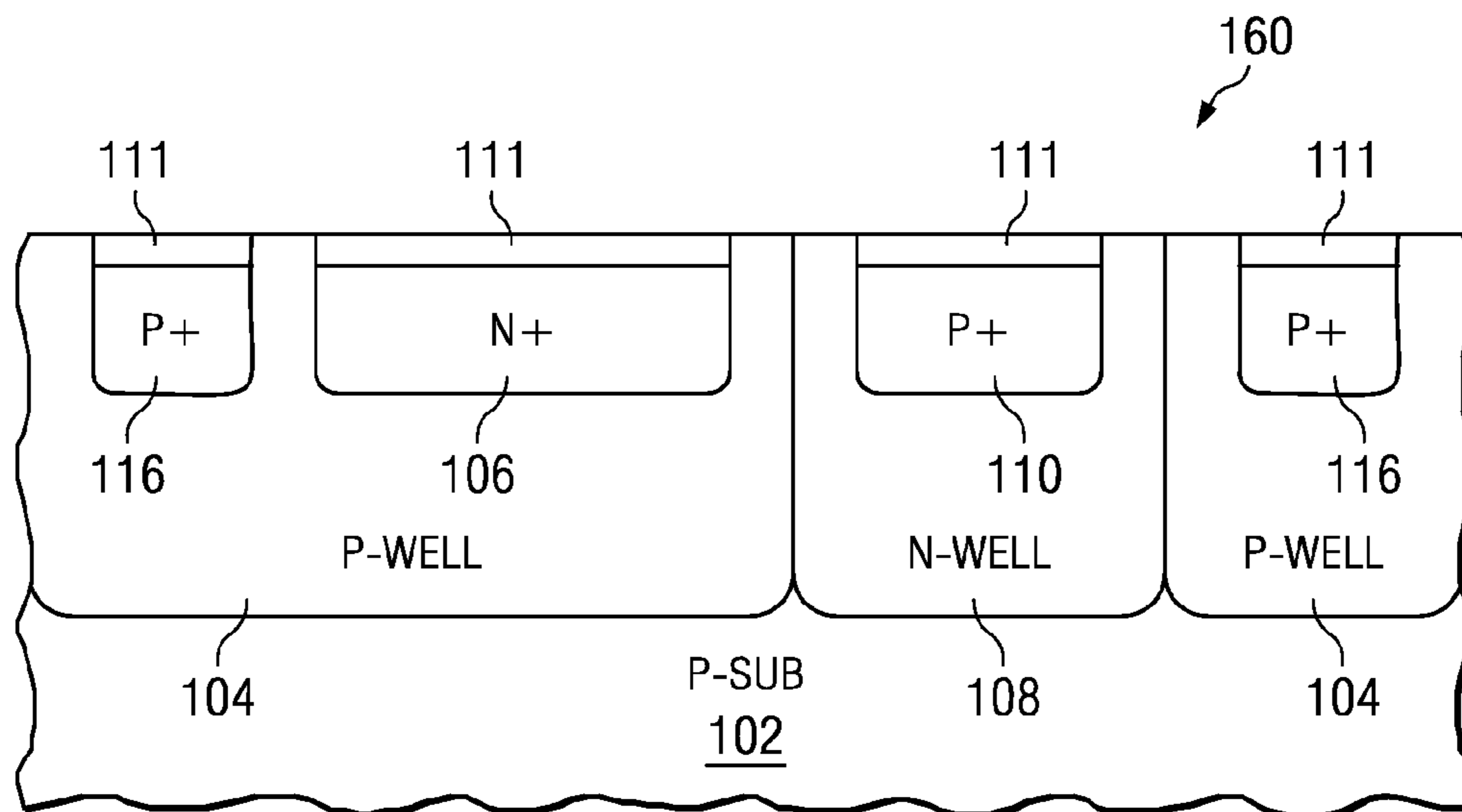


FIG. 2c

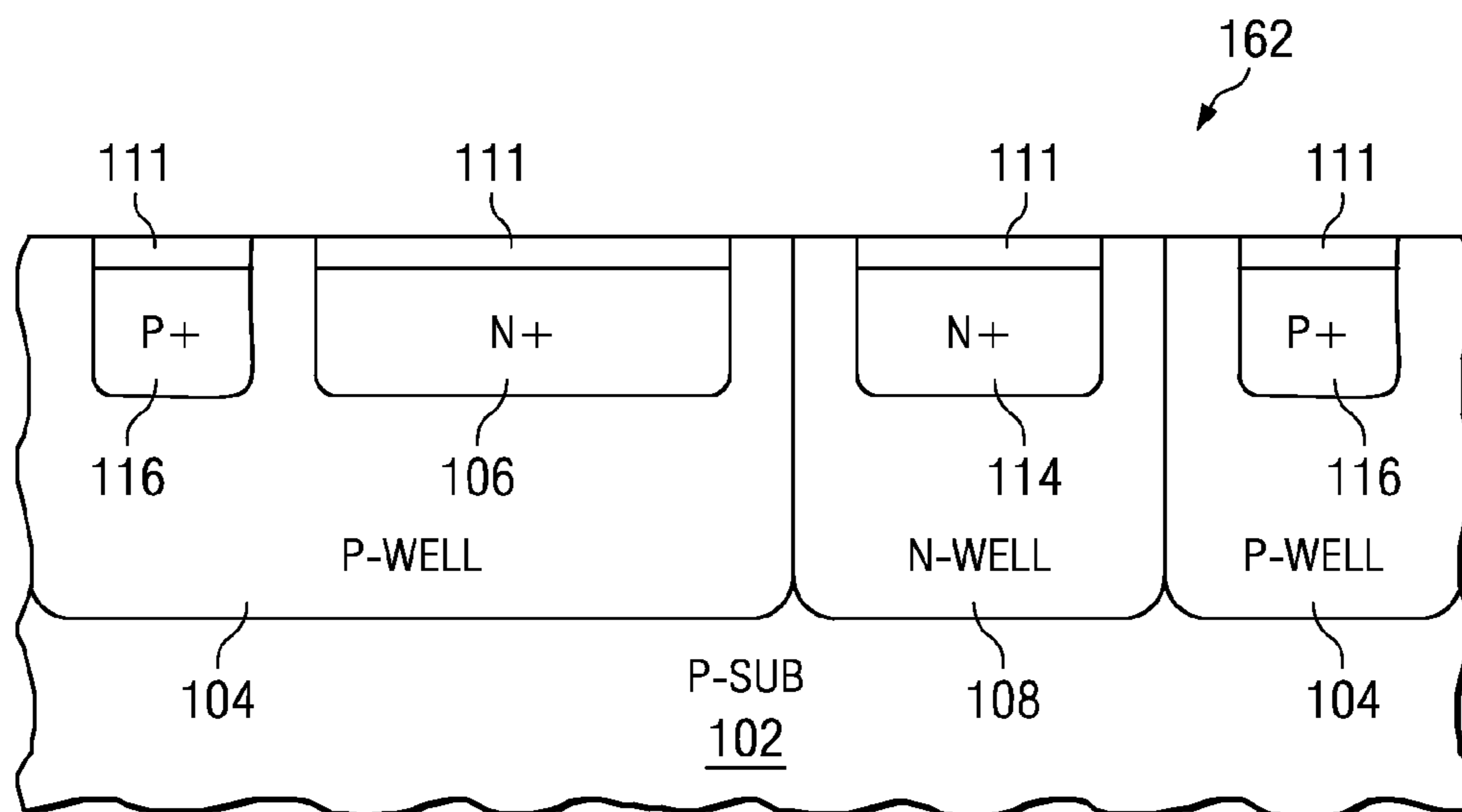


FIG. 2d

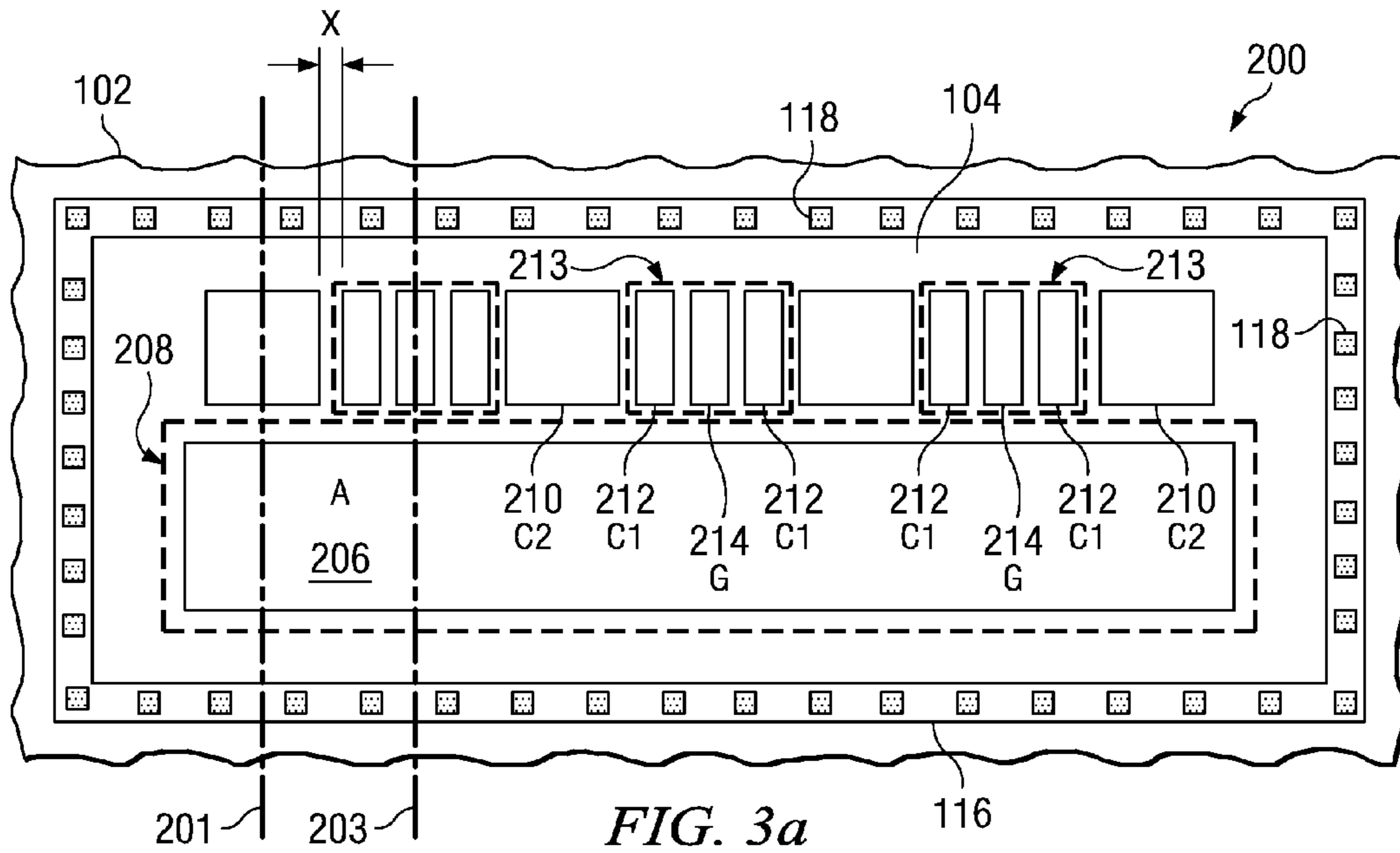


FIG. 3a

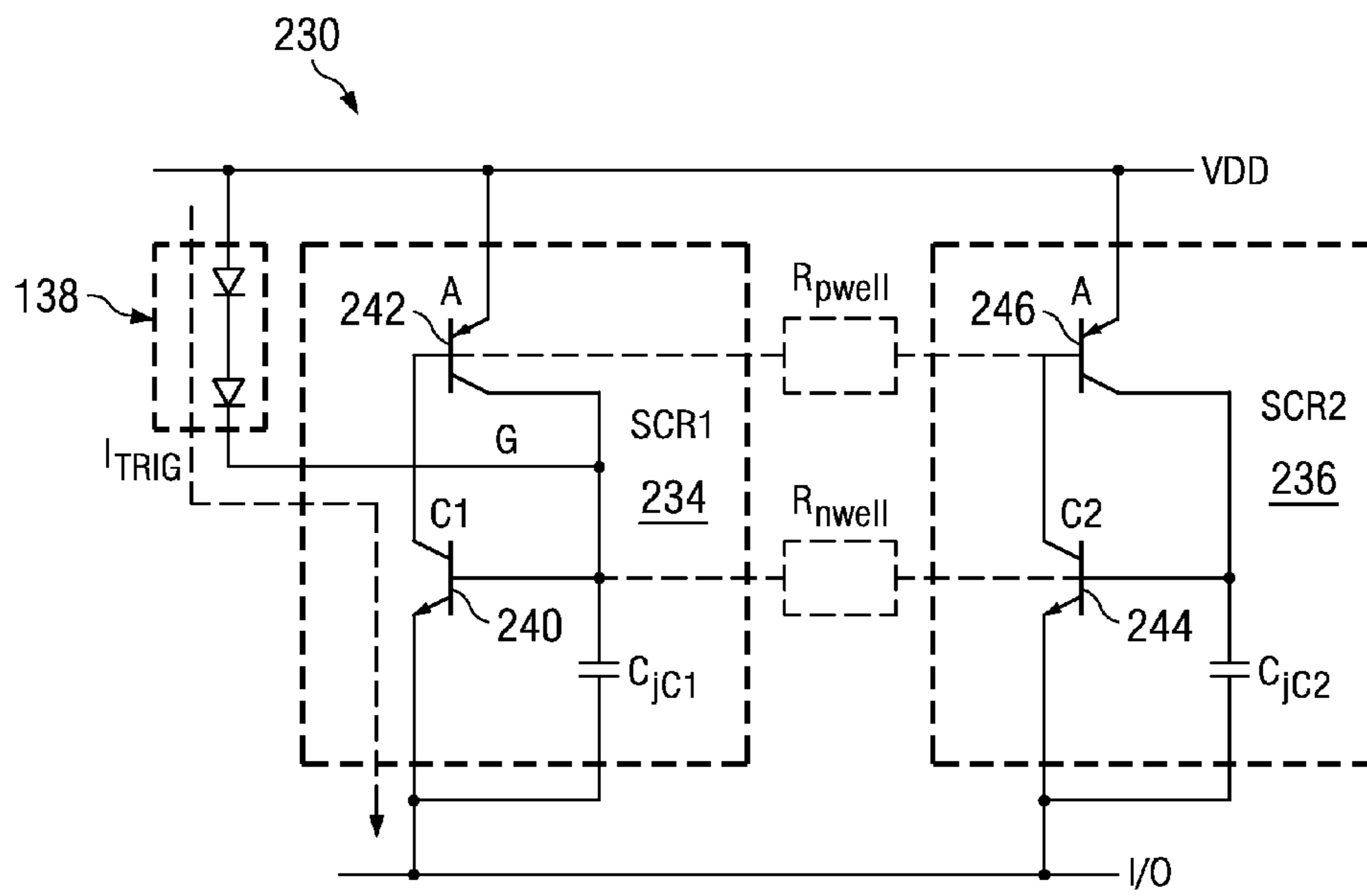


FIG. 3b

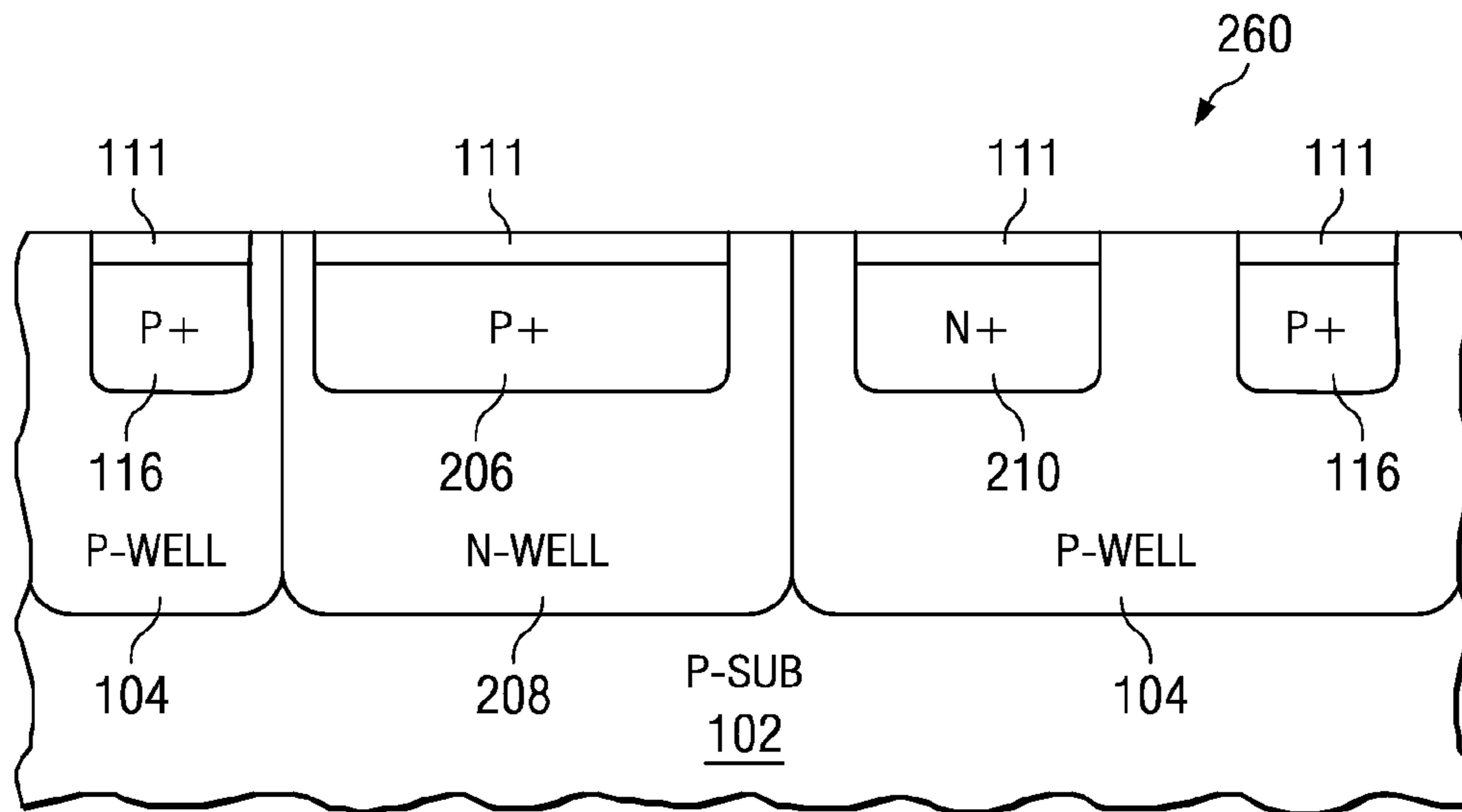


FIG. 3c

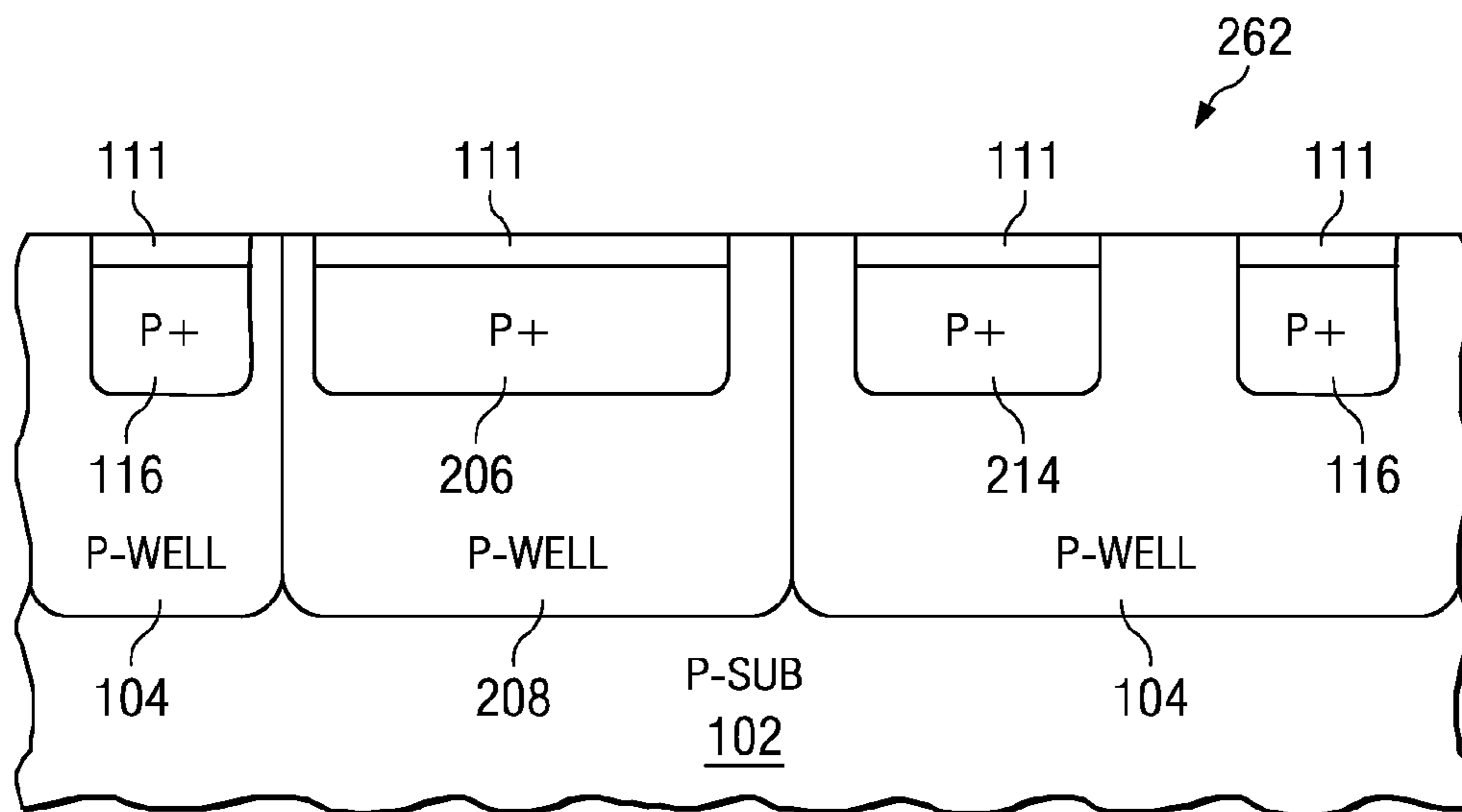


FIG. 3d

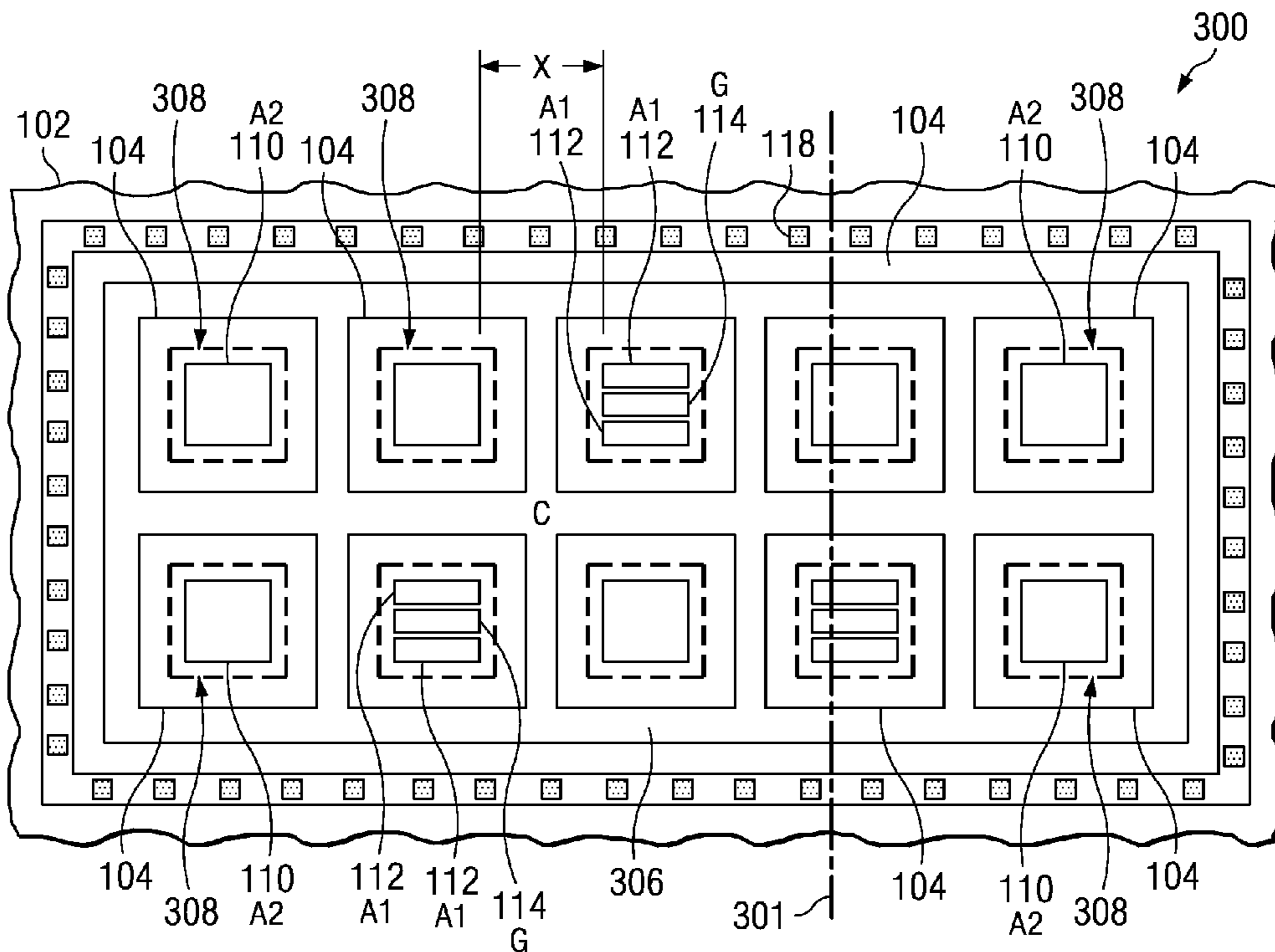


FIG. 4a

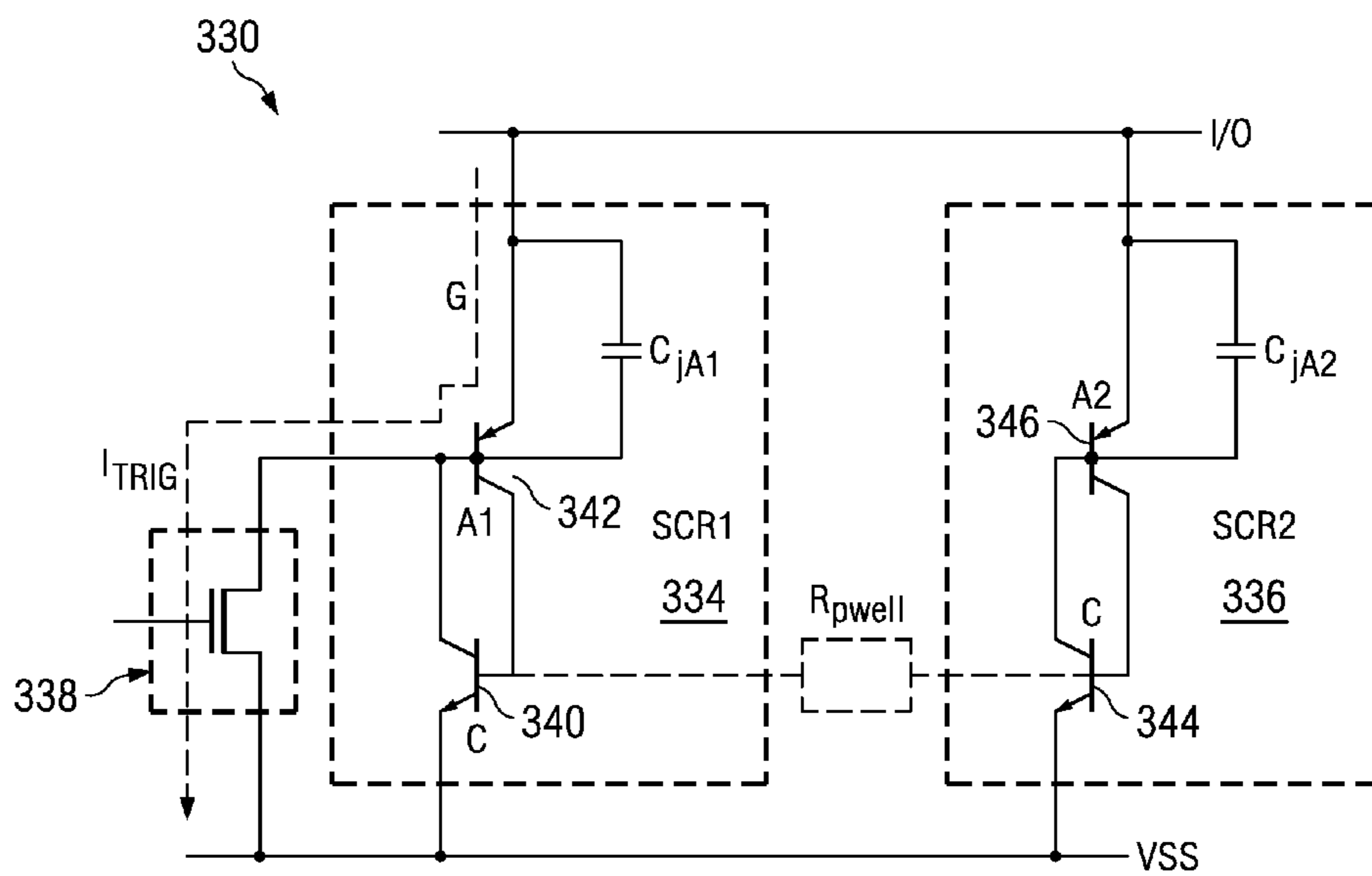


FIG. 4b

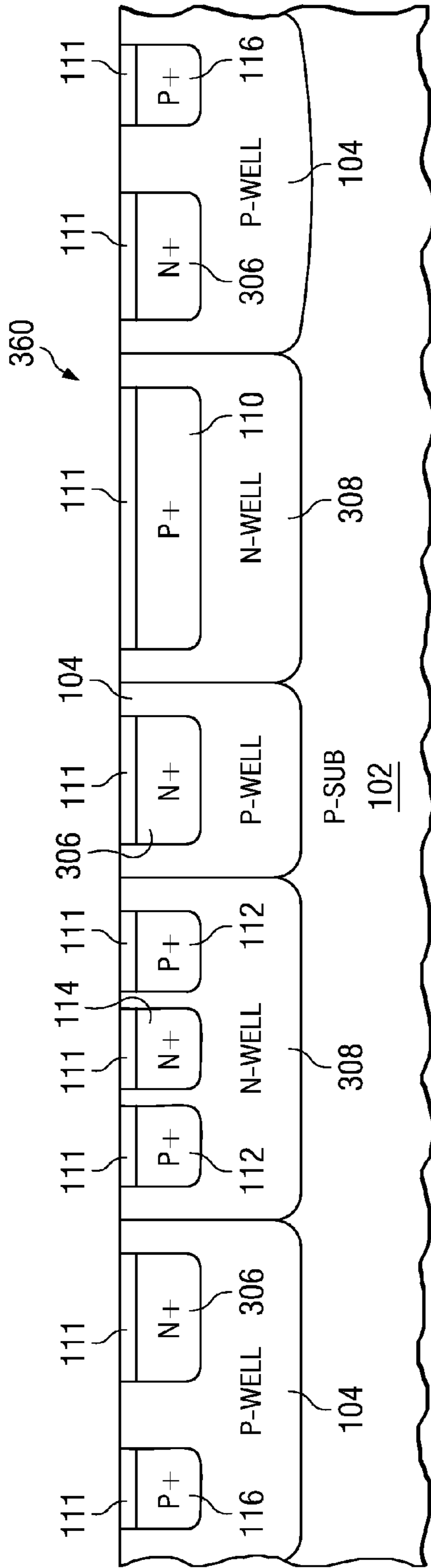


FIG. 4c

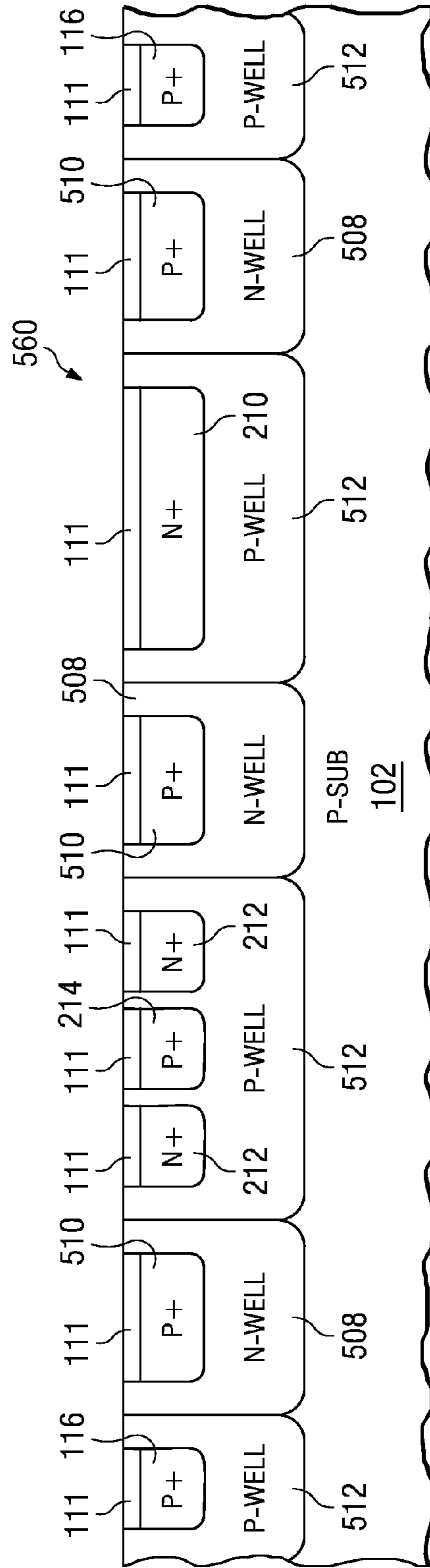
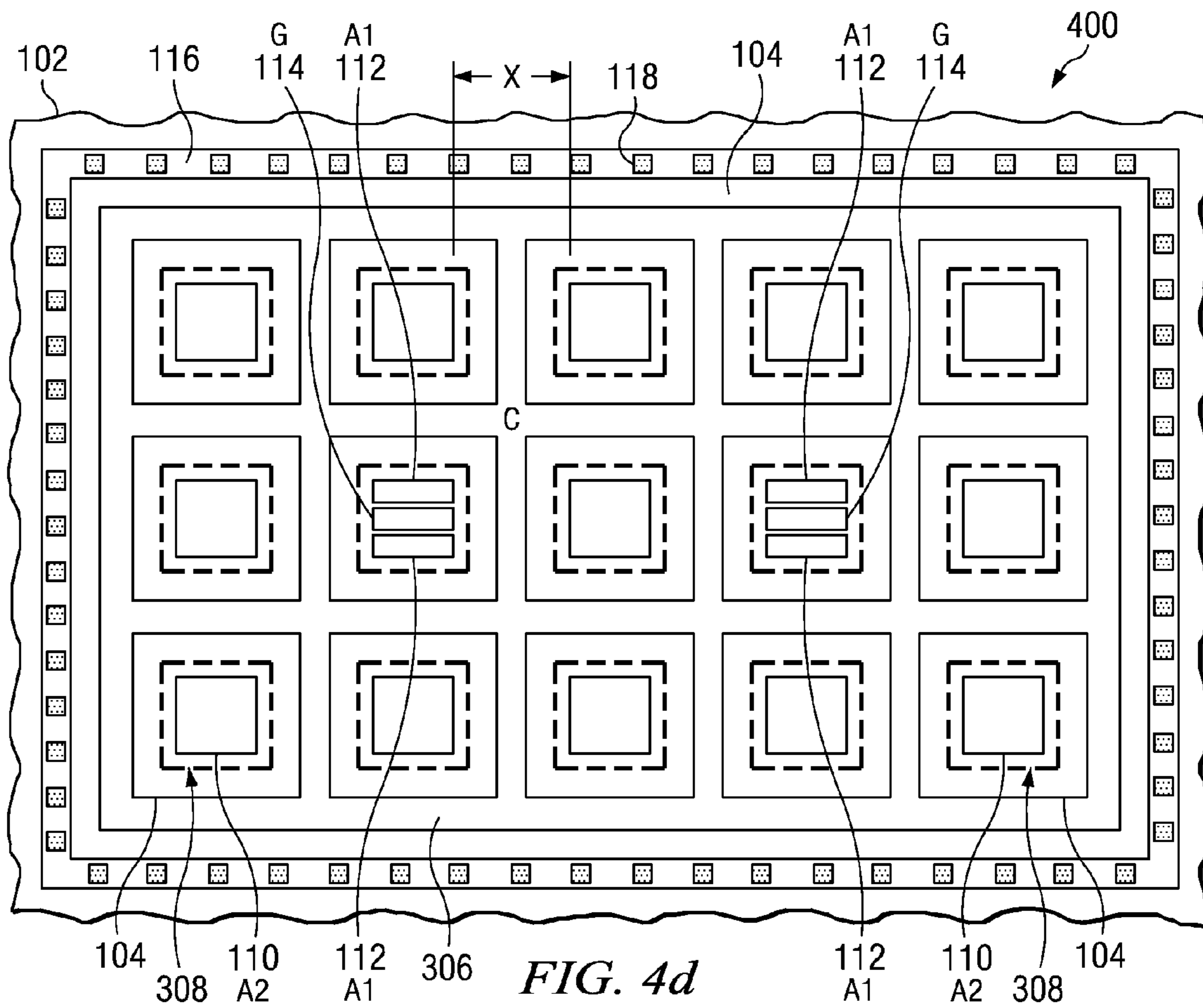


FIG. 5c



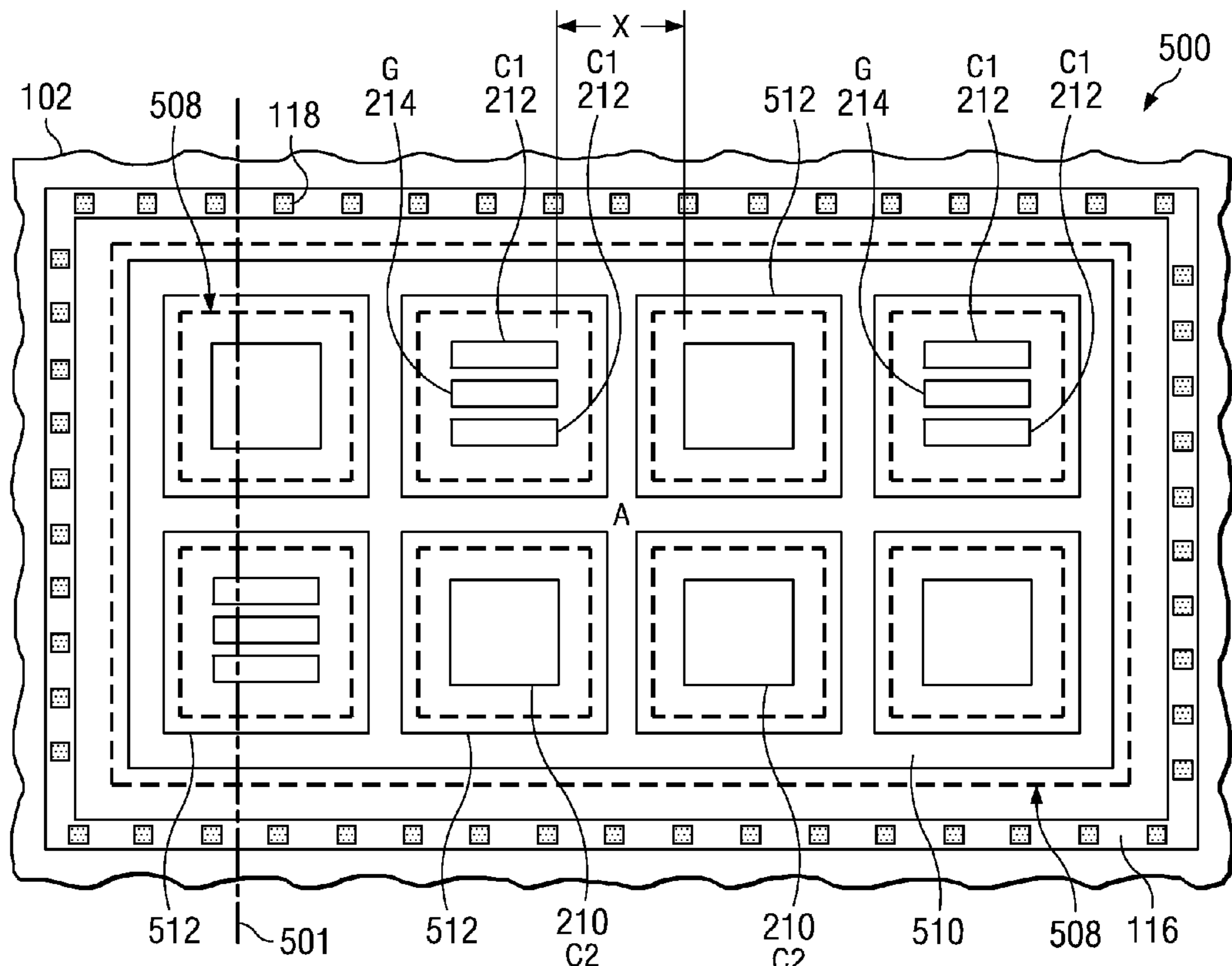


FIG. 5a

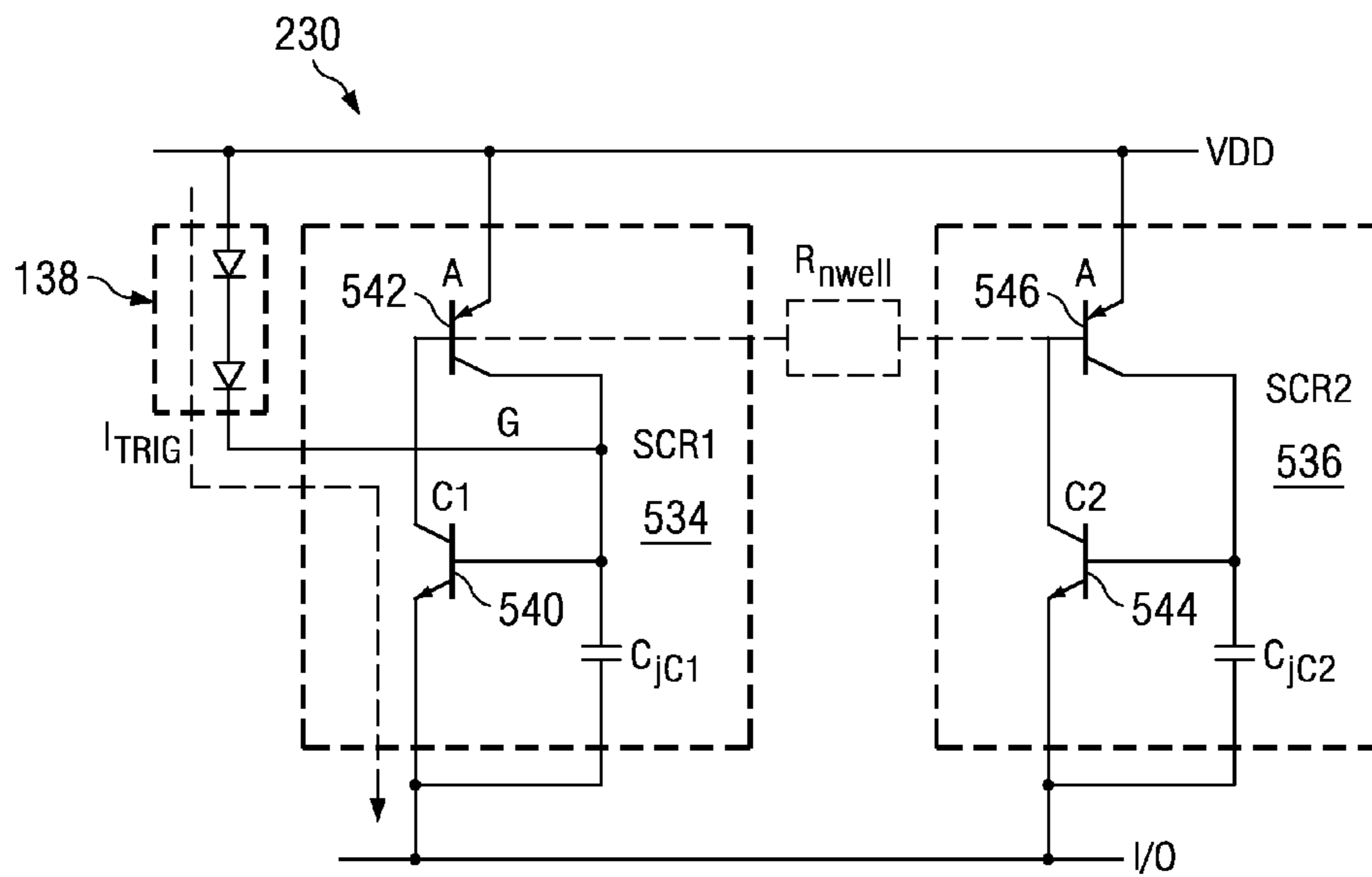


FIG. 5b

1

SEMICONDUCTOR ESD DEVICE AND METHOD OF MAKING SAME

This is a divisional application of U.S. application Ser. No. 12/138,208, entitled "Semiconductor ESD Device and Method of Making Same", which was filed on Jun. 12, 2008 now U.S. Pat. No. 7,800,128 and is incorporated herein by reference.

TECHNICAL FIELD

This invention relates generally to semiconductor devices and methods, and more particularly to an ESD protection device and method.

BACKGROUND

As electronic components are getting smaller and smaller along with the internal structures in integrated circuits, it is getting easier to either completely destroy or otherwise impair electronic components. In particular, many integrated circuits are highly susceptible to damage from the discharge of static electricity. Generally, electrostatic discharge (ESD) is the transfer of an electrostatic charge between bodies at different electrostatic potentials or voltages, caused by direct contact or induced by an electrostatic field. The discharge of static electricity, or ESD, has become a critical problem for the electronics industry.

Device failures resulting from ESD events are not always immediately catastrophic or apparent. Often, the device is only slightly weakened but is less able to withstand normal operating stresses. Such a weakened device may result in reliability problems. Therefore, various ESD protection circuits should be included in a device to protect its various components.

When an ESD pulse occurs on a transistor, the extremely high voltage of the ESD pulse can break down the transistor and can potentially cause permanent damage. Consequently, the circuits associated with the input/output pads of an integrated circuit need to be protected from ESD pulses to prevent such damage.

Integrated circuits and the geometry of the transistors that make up the integrated circuits continue to be reduced in size and the transistors are arranged closer together. A transistor's physical size limits the voltage that the transistor can withstand without being damaged. Thus, breakdown voltages of transistors are lowered and currents capable of overheating components are more frequently reached by the voltages and currents induced by an ESD event.

In order to remedy problems with lower device yields stemming from ESD events, the semiconductor industry has recommended a number of different ESD event models to be used for ESD test criteria and design goals. One of these ESD event models, the charged device model (CDM), models rapid ESD events likely to occur during the semiconductor manufacturing and handling process. The ESD events modeled by CDM represent instantaneous discharge. Such an ESD event may consist of a peak current a few Amps and may last for about 1 ns.

Designing an ESD device triggerable in less than 1 ns is challenging because most ESD devices must be designed to be physically large in order to handle high ESD currents and voltages. The large device capacitance associated with the relatively large physical size of an ESD device, however, increases the RC time constant of the ESD device, which increases the turn-on time of the ESD device. ESD device design for the CDM model, therefore entails achieving a

2

difficult balance between device speed and current handling capability. Thus, there is a need for ESD protection devices that can be rapidly triggered, yet still conduct large currents.

SUMMARY OF THE INVENTION

In one embodiment, a semiconductor device includes an ESD device region disposed within a semiconductor body of a first conductivity type, and a plurality of first device regions of a first conductivity type disposed on a second device region of the second conductivity type, where the second conductivity type is opposite the first conductivity type. Also included is a plurality of third device regions disposed on the second device region, where the third device regions comprise a sub-region of the first conductivity type and a sub-region of the second conductivity type. The plurality of first regions and third regions are distributed on the second device region such that the third regions are not directly adjacent to each other. A fourth device region of the first conductivity type adjacent to the second device region and a fifth device region of the second conductivity type disposed within the fourth device region are also included. The first, second, third fourth and fifth regions are all disposed within the ESD region, and first device regions, the sub-regions of the first conductivity type of the third device region, the second device region, the fourth device region and the fifth device region form a silicon controlled rectifier (SCR).

The details of one or more embodiments of the invention are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the invention will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

FIGS. 1a-1c are circuit diagrams of an embodiment of the present invention;

FIGS. 2a-2d illustrate a layout view, corresponding circuit model and cross sections of a 1-dimensional embodiment of the present invention;

FIGS. 3a-3d illustrate a layout view, corresponding circuit model and cross sections of a complimentary 1-dimensional embodiment of the present invention;

FIGS. 4a-4d illustrate a layout view, corresponding circuit model and cross sections of a 2-dimensional embodiment of the present invention; and

FIGS. 5a-5c illustrate a layout view, corresponding circuit model and cross sections of a complimentary 2-dimensional embodiment of the present invention.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

The making and using of the presently preferred embodiments are discussed in detail below. It should be appreciated, however, that the present invention provides many applicable inventive concepts that can be embodied in a wide variety of specific contexts. The specific embodiments discussed are merely illustrative of specific ways to make and use the invention, and do not limit the scope of the invention.

The present invention will be described with respect to preferred embodiments in a specific context, namely a silicon

controlled rectifier (SCR) ESD structure. The invention may also be applied, however, to other semiconductor structures.

FIG. 1a illustrates a known ESD protection device 10. This circuit includes an SCR 12 that includes a p-type anode 18, an n-type cathode 24, an n-type n-base SCR region 20, and a p-type p-base SCR region 22. The anode 18 and a trigger element 30 are coupled to a node to be protected 16 and a reference node 34, which is typically ground. The trigger element 30 causes a trigger current I_{TRIG} 32 to flow whenever the voltage at node 16 exceeds a certain threshold. Typical required trigger thresholds are between 1V and 20V. The presence of a trigger current I_{TRIG} 32 causes the SCR to conduct a large current, I_{ESD} 36.

FIG. 1b is an equivalent circuit representation of ESD protection device 10 in a non-conducting state where the voltage at node 16 is less than the threshold of the trigger device, and the SCR is not conducting a large current I_{ESD} 36. In the non-conducting state, the SCR can be modeled as a bipolar latch 12 that includes bipolar junction transistor (BJT) PNP device 40, and a BJT NPN device 42. The representative PNP device is made up of the p-type anode 18 as the emitter, the n-base region 20 as the base, and p-base region 22 as the collector. The representative NPN device is made up of n-base region 20 as the collector, the p-base region 22 as the base, and the n-type cathode 24 as the emitter. When trigger current I_{TRIG} 32 flows from the base of representative PNP 40 in response to a voltage transient at node 16, the collector of the representative PNP 40 is pulled high, which turns on NPN 42, which pulls the base of PNP 40 down toward the potential at reference node 34, thereby latching the bipolar latch 12 and causing a large current I_{ESD} 36 to flow.

Turning to FIG. 1c, once the SCR 12 is latched, the SCR can be modeled as a forward biased PIN diode where the intrinsic region 50 includes the n-base region 20 and the p-base region 22. When the SCR 12 is turned on I_{ESD} 36 will continue to flow even if I_{TRIG} 32 is no longer applied. An SCR fabricated in a submicron process will typically conduct 10 mA to 100 mA per μm width. The SCR will stop conduction once I_{ESD} 36 falls below a holding current, typically 1 μA to 1 mA of per μm width.

FIG. 2a illustrates a layout view of an SCR 100 of an embodiment of the present invention, a 1-dimensional ESD device that can be used to protect a positive voltage transient on a node coupled to its anode. The anode is formed by p+ regions 110 and 112, the n-base region is formed by n-well 108, the p-base region is formed by p-well 104, and the cathode is formed by n+ region 106. An optional substrate ring formed by p+ region 116 surrounds the active portion of SCR 100. Anode regions 110 and 112, are spaced apart from each other by distance x, which is preferably sized to the minimum allowable spacing, for example 100 nm in an embodiment process. Keeping distance x at a short distance is preferable because it improves coupling within ESD device 100. Also included are trigger contact regions formed by n+ regions 114. Anode regions 112 and trigger contact regions 114 form triggered anode units 113. In alternative embodiments of the present invention, other types of regions can be used for the device regions specified hereinabove. Furthermore, non-minimum spacing between anode regions 110 and 112 can also be used depending on the particular application semiconductor process technology.

Anodes 110 and 112, trigger contacts 114, cathode 106 and optional substrate ring 116 preferably have contacts on the upper surface of these regions. Only the contacts 118 on the optional substrate ring are shown for clarity, however, it should be noted all of these regions have contacts. In preferred embodiments of the present invention, contacts to

anode regions 110 and 112 are coupled to a node to be protected, cathode region 106 is coupled to ground, and trigger contact regions 114 are coupled to a trigger device. For the sake of clarity of explanation herein, anode region 112 has further been labeled A1, anode region 110 is labeled A2, trigger contact region 114 is labeled G and cathode region 106 is labeled C.

Turning to FIG. 2b, a circuit model 130 of the ESD device of FIG. 2a is shown. Bipolar latch 134 is representative of a local SCR (SCR1) formed by one of triggered anode units 113 (FIG. 2a). Node A1 at the emitter of PNP 142 corresponds to anode regions 112 (FIG. 2a), node G at the base of PNP 142 corresponds to the trigger region 114 (FIG. 2a), and node C at the emitter of NPN 140 corresponds with cathode region 106 (FIG. 2a). In preferred embodiments of the present invention, trigger 138 preferably resides on the same integrated circuit as ESD device 100 (FIG. 2a). Trigger 138 can be made from a diode, a plurality of series connected diodes, a transistor, or any other suitable component capable of generating trigger current, I_{TRIG} , during an ESD event. For example, two series connected n-well diodes may be used to form trigger 138. If two series connected diodes are used, Bipolar latch 142 will trigger when the potential difference between node I/O and VSS is about 3 VBEs, or between about 1.8V and about 10V, or even higher depending on the particular characteristics of the components, such as trigger element 30, and the semiconductor process being used.

Bipolar latch 136, on the other hand, is representative of a local SCR (SCR2) formed by one of the non-triggered anode regions 110 (FIG. 2a). Node A2 at the emitter of PNP 146 corresponds with anode regions 110 (FIG. 2a) and node C at the emitter of NPN 144 corresponds with cathode region 106 (FIG. 2a). Rather than being triggered by an adjacent trigger contact region 114 as is bipolar latch 134, Bipolar latch 136 is triggered by currents within n-well 108 (FIG. 2a) that are generated by trigger device 138 and currents from other anode regions 112 and 110 flowing into n-well 108 as the ESD device 100 (FIG. 2a) begins to conduct during an ESD event.

The speed at which ESD device 130 can respond to an ESD event at node I/O depends primarily on the RC time constant formed by C_{jA1} , R_{pwell} and R_{nwell} . C_{jA1} represents the capacitance between the p+ region of anode 112 and n-well region of n-base region 108, R_{pwell} represents the resistance of p-well region 104 between n-well 108 and n+ cathode region 106, and R_{nwell} represents the resistance of n-well region 108. During normal, non-ESD operation, the capacitance seen by node I/O is relatively low because trigger device 138 and the base-emitter junction of PNP 142 are not conducting current. As node I/O increases in voltage however, trigger device starts to conduct current, thereby lowering its own impedance and forcing the base-emitter junction of PNP 142 to conduct current and become more forward biased. As the base-emitter junction of PNP 142 becomes more forward biased, the junction's diffusion capacitance significantly increases causing C_{jA1} to increase.

In preferred embodiments of the present invention, two different types of SCR's are coupled together within the same ESD device. The first type of device as represented by SCR1 contains trigger regions 114 with adjacent anode regions 112 (FIG. 2a). The second type of device represented by SCR2 contains anode regions 110. Anode A1 of SCR1 preferably has the smallest possible area in order to minimize the capacitance between p+ region 112 and n-well 108. The area of anode A2 of SCR2, on the other hand, is larger to handle more ESD current.

As the ESD device begins to turn on, capacitance C_{jA1} at anode A1 of SCR1 becomes the dominant contributor to the

capacitance at node I/O. Because SCR2 is spaced further away from trigger regions 114 than SCR1, capacitance C_{jA2} remains small when the ESD device initially turns on. Because of its small physical size, capacitance C_{jA1} at SCR1 is lower than the capacitance of conventional SCR ESD devices. Under fast CDM conditions, the ESD pulse triggers SCR1 first and consecutively triggers SCR2.

Dividing the SCR into regions SCR1 and SCR2 allows minimizing the capacitance of the initially triggered part of the overall SCR, and therefore improves the response time of the entire device during the triggering event while maintaining a high overall level of ESD robustness and a high overall current handling capability.

Trigger tap regions 114 (also labeled as G) are preferably split into a small number of smallest possible size trigger tap regions. In conventional SCR devices, only one or two filaments of current are present in the device during triggering. By splitting the trigger tap regions, more current filaments can be present during device triggering. In some embodiments of the present invention, there can be as many current filaments as there are A1 anode regions 112. By having more filaments of current present in the device during triggering, the triggering resistance in embodiment SCR devices can be lower than the triggering resistance of SCR devices made according conventional embodiments.

Embodiments of the present invention are advantageous over the conventional embodiments, because in conventional SCR based ESD devices that use only a single SCR, or multiple SCRs that each comprise a trigger region, the turn-on capacitance is a strong function of ESD device size and current handling capacity. For conventional devices, the increase in turn-on capacitance at node I/O increases in voltage is a major contributing factor in slower turn-on times.

FIG. 2c illustrates cross section 160 of ESD device 100 taken at line 101 (FIG. 2a). N+ cathode region 106 and optional p+ substrate ring 116 are shown disposed in p-wells 104, and p+ anode 110 is shown disposed in n-well 108. In the depicted embodiment, p-wells 104 and n-well 108 reside in p-type substrate 102, however, in alternative embodiments of the present invention, other types of substrates, such as n-type, SOI and EPI, can be used, for example. FIG. 2d, on the other hand, illustrates a cross section 160 of ESD device 100 taken at line 103 (FIG. 2a). N+ cathode region 106 and optional p+ substrate ring 116 are shown disposed in p-wells 104, and n+ trigger region 114 is shown disposed in n-well 108.

N-type cathode region 106 and trigger region 114 are preferably made from an n-type source/drain implant. Typically, the cathode region 106 and trigger region 114 have the same doping because the cathode region 106 and trigger region 114 can be implanted at the same mask and processing step. For example, typically Arsenic ions can be implanted with a dose of about $1 \times 10^{14} \text{ cm}^{-2}$ to about $5 \times 10^{21} \text{ cm}^{-2}$ and an implant energy between about 10 keV and about 50 keV. In other embodiments, other materials, such as Phosphorus or Germanium, can be implanted. The resulting doping concentration for these n-type regions is typically greater than 10^{21} cm^{-3} .

The p-type anode 110 and 112 and optional substrate ring 116 are preferably made from a p-type source/drain implant. For example, boron ions can be implanted with a dose of about $5 \times 10^{13} \text{ cm}^{-2}$ to about $5 \times 10^{21} \text{ cm}^{-2}$ and an implant energy between about 5 keV and about 50 keV. In other embodiments, other materials, such as BF_2 , can be implanted. The final doping concentration for these p-type regions is typically greater than 10^{21} cm^{-3} . Again, these p-type regions are preferably implanted at the same mask step. Alternatively, these regions may be implanted during different mask steps.

A portion of the top surface of anode regions 110 and 112, cathode region 106 and optional substrate ring 104 include silicided regions 111 on top of which contacts (not shown) are fabricated. These silicided regions are fabricated using conventional techniques.

In preferred embodiments, p-wells 104 and n-wells 108 are first fabricated in a p-type substrate 102 of a semiconductor wafer. N-type cathode region 106, n-type trigger region 114, and p-type anode 110 and 112 and p-type optional substrate ring 116 are then fabricated within these wells as shown in FIGS. 2c-2d. Silicide 111 is formed on the surface of N-type cathode region 106 n-type trigger region 114, and p-type anode 110 and 112 and p-type optional substrate ring 116, and contacts (not shown) are then coupled to silicide layers 111. Semiconductor processing continues with the application of metallization and dielectric layers until processing is complete. Alternatively, other processing steps and sequences may be used.

Turning to FIG. 3a, a complimentary layout 200 of a 1-dimensional speed-optimized ESD device is shown which can be used to protect a node coupled to its cathode from a negative voltage transient. In complementary layout 200, the SCR is divided into multiple SCR devices by breaking up the cathode regions into multiple sections in a manner analogous to how the anode is divided in the embodiment of FIG. 2a. The cathode is formed by n+ regions 210 and 212, the p-base region is formed by p-well 104, the n-base region is formed by n-well 208, and the anode is formed by p+ region 206. An optional substrate ring formed by p+ region 116 surrounds the active portion of SCR 200. As was done with the anode regions in FIG. 2a, cathode regions 210 and 212, are spaced apart from each other by distance x, which is preferably sized to the minimum allowable spacing, for example 100 nm in an embodiment process. Again as with the embodiment of FIG. 2a, keeping distance x to a short distance is preferable because it improves coupling within ESD device 200. Also included are trigger contact regions formed by p+ regions 214. Anode regions 212 and trigger contact regions 214 form triggered anode units 213. In alternative embodiments of the present invention, other types of regions can be used for the device regions specified hereinabove. Furthermore, non-minimum spacing between cathode regions 210 and 212 can also be used depending on the particular application's semiconductor process technology. In the depicted embodiments, ESD device 200 resides in a p-type substrate 102, however, in alternative embodiments of the present invention, other types of substrates, such as SOI, EPI, or n-type can be used.

FIG. 3b shows an equivalent circuit representation 230 of 1-dimensional complementary ESD device 200 (FIG. 3a). Similar to the model in FIG. 3a, SCR1 and SCR2 are represented by two bipolar latches 234 and 236. In the complementary embodiment, however, anode node A is coupled to VDD and cathode node C is coupled to node I/O, which is typically coupled to a circuit to be protected (not shown). In the complementary embodiment, however, trigger device 138, whose functionality and architecture is described hereinabove, is coupled between VDD and n-base region 104 (FIG. 3a). In alternative embodiments, however, trigger device may be coupled to different nodes within the integrated circuit; for example, a dedicated ESD supply node may be used instead of VDD.

In the complementary 1-dimensional embodiment, bipolar latch 234 is representative of a local SCR (SCR1) formed by one of triggered cathode units 213 (FIG. 3a). Node C1 at the emitter of NPN 240 corresponds to cathode regions 212 (FIG. 3a), node G at the base of NPN 240 corresponds to the trigger

region **214** (FIG. **3a**), and node A at the emitter of PNP **242** corresponds with anode region **206** (FIG. **3a**).

Bipolar latch **236**, on the other hand, is representative of a local SCR (SCR2) formed by one of the non-triggered cathode regions **210** (FIG. **3a**). Node C2 at the emitter of NPN **244** corresponds with cathode regions **210** (FIG. **3a**) and node A at the emitter of PNP **246** corresponds with anode region **206** (FIG. **3a**). During triggering, bipolar latch **236** is triggered by currents within p-well **104** (FIG. **3a**) that are generated by trigger device **138** and currents from other cathode regions **212** and **210** flowing into p-well **104** as the ESD device **200** (FIG. **3a**) begins to conduct during an ESD event.

Triggering of complementary 1-dimensional ESD device **200** (FIG. **3a**) functions similarly to the triggering of the non-complementary ESD Device **100** (FIG. **2a**), except that in the complementary layout, the base-emitter capacitance C_{jC1} of NPN **240** formed by the junction between n+ cathode region **212** (FIG. **3a**) and p-well p-base region **104** is the dominant capacitance during turn-on rather than C_{jA1} . In complementary layout embodiments, the RC time constant of the ESD device during activation is dominated by C_{jC1} , R_{pwell} and R_{nwell} .

FIG. **3c** illustrates a cross section **260** of ESD device **200** taken at line **201** (FIG. **3a**). N+ cathode region **210** and optional p+ substrate ring **116** are shown disposed in p-wells **104**, and p+ anode **206** is shown disposed in n-well **208**. In the depicted embodiment, p-wells **104** and n-well **208** reside in p-type substrate **102**, however, in alternative embodiments of the present invention, other types of substrates, such as SOI, EPI, or n-type can be used. FIG. **3d**, on the other hand, illustrates a cross section **262** of ESD device **200** taken at line **203** (FIG. **3a**). FIG. **3d** is similar to FIG. **3c**, with the exception that p+ trigger region **214** is shown disposed in p-well **104**. Silicide regions **111** and contacts (now shown) are provided as described hereinabove with respect to FIGS. **2c** and **2d**. Processing of device **200** (FIG. **3a**) also proceeds as described hereinabove with respect to FIGS. **2a-2d** using similar implants and mask steps for p+ and n+ regions.

The embodiments shown in FIGS. **2a** and **3a** are 1-dimensional speed-optimized devices suitable for both human body model (HBM) pulses lasting about 200 ns as well as CDM pulses lasting only about 1 ns to about 5 ns. These embodiments are also suitable to address the requirements of machine model (MM) ESD protection. In other embodiments of the present invention, such as the embodiments shown in FIGS. **4a**, **4d**, and **5a**, a 2-dimensional layout can be used.

Turning to FIG. **4a**, 2-dimensional embodiment of the present invention is shown. N+ cathode region **306** is formed as a grid that surrounds triggered and non-triggered anode regions **110** and **112**. Each anode region has a p-well p-base region **104** and an n-well n-base region **308**. In alternative embodiments, however, these p-base and n-base regions may comprise other types of regions, for example substrate and EPI regions. In the triggered anode regions, p+ anode regions **112** reside in n-well n-base regions **308** along n+ trigger contact regions **114**. It should be noted that n+ cathode region **306** is disposed above p-well region **104**, thereby allowing coupling between anodes through p-well **104**. As discussed hereinabove with respect to the embodiment of FIG. **2a**, anode regions **112** and trigger regions **114** are preferably sized to a minimum geometry along at least one dimension and distance x between anode regions is preferably about 1 μm , although in alternative embodiments other dimensions may be used. In the non-triggered anode regions, p+ anode regions **110** reside in n-well n-base regions. Anode regions **110** are preferably sized larger than anode regions **112** in order to conduct higher currents.

FIG. **4b** shows a circuit model representation **330** of the 2-dimensional ESD structure **300** shown in FIG. **4a**. Bipolar latch **334** represents triggered anode regions (designated as SCR1) and bipolar latch **336** represents non-triggered anode regions (designated as SCR2). Trigger device **338** is illustrated as an NMOS device in this embodiment, however, other trigger devices, such as diodes can be used as described hereinabove. It should be noted that in embodiments of the present invention, additional trigger circuitry, such as RC networks and inverter chains, may be coupled to the gate of NMOS device within trigger device **338**. Turn-on operation of the 2-dimensional ESD device functions similarly to the ESD device of FIGS. **2a-2b**, however, coupling between a triggered device (SCR1) and a non-triggered device (SCR2) includes current flowing underneath cathode **306** in p-well **104**. Unlike the ESD device of FIGS. **2a-2b**, however, n-well regions **308** (FIG. **4a**) are decoupled.

In preferred embodiments of the present invention, the geometric distribution of triggered and non-triggered anode regions for 2-dimensional ESD structure is optimized to minimize turn-on time for a given current handling capability. To this end, a triggered anode region is preferably not situated along the length or width of a non-triggered anode region, as shown in FIG. **4a**.

FIG. **4c** illustrates cross section **360** of ESD device **300** taken at line **301** (FIG. **4a**). N+ cathode regions **306** and optional p+ substrate ring **116** are shown disposed in p-wells **104**, and p+ anodes **110** and **112** are shown disposed in n-well **308**. In the depicted embodiment, p-wells **104** and n-well **308** reside in p-type substrate **102**, however, in alternative embodiments of the present invention, other types of substrates, such as EPI, SOI, or n-type can be used. Silicide regions **111** and contacts (now shown) are provided as described hereinabove with respect to FIGS. **2c** and **2d**. Processing of device **300** (FIG. **4a**) also proceeds as described hereinabove with respect to FIGS. **2a-2d** using similar implants and mask steps for p+ and n+ regions.

FIG. **4d** shows an alternative embodiment layout of a 2-dimensional ESD structure **400**. Instead of having three triggered anode regions and six non-triggered anode regions on a 2x5 grid as was shown in FIG. **4a**, FIG. **4d** shows only two triggered anode regions for 13 non-triggered anode regions on a 3x5 grid. The operation of ESD structure **400** functions in accordance with the embodiments shown in FIGS. **4a-4b** and described hereinabove. ESD structure **400**, however, may handle more current than ESD structure **300** (FIG. **4a**) because of its increased number of anode regions, and have a different turn-on time characteristic from ESD structure **300** (FIG. **4a**). It should be noted that in further alternative embodiments of the present invention, other two dimensional grid sizes, non-rectangular regions, and other ratios of triggered to non-triggered anode regions can be used.

Turning to FIG. **5a**, a complementary layout of a 2-dimensional ESD structure **500** is shown. In the 2-dimensional complementary embodiment of the present invention, p+ anode region **510** is formed as a grid that surrounds triggered and non-triggered cathode regions **210** and **212**. Each cathode region has an n-well n-base region **508** and a p-well p-base region **512**. In alternative embodiments, however, these p-base and n-base regions may comprise other types of regions, for example substrate and EPI regions. In the triggered cathode regions, n+ cathode regions **212** reside in p-well p-base regions **512** along a p+ trigger contact regions **214**. It should be noted that p+ anode region **510** is disposed above n-well region **508**, thereby allowing coupling between anodes through n-well **508**. As discussed hereinabove with respect to the embodiment of FIG. **3a**, cathode regions **212**

and trigger regions **214** are preferably sized to a minimum geometry along at least one dimension and distance x between cathode regions is preferably about $1\ \mu\text{m}$, although in alternative embodiments other dimensions may be used. In the non-triggered cathode regions, $n+$ cathode regions **210** reside in p -well p -base regions **512**. Cathode regions **210** are preferably sized larger than cathode regions **212** in order to conduct higher currents.

The embodiment of FIG. **5a** functions in accordance to the circuit model shown in FIG. **5b**. Triggered cathode regions **212** and its surrounding regions are modeled by bipolar latch **534** (SCR1) containing bipolar transistors **540** and **542**, and non-triggered cathode regions **210** are modeled by bipolar latch **526** (SCR2) containing transistors **544** and **546**. Coupling between triggered and non-triggered regions occur through n -well regions **508** that extend underneath anode regions **510**. Trigger device **138** activates the ESD circuit as described hereinabove with respect to FIG. **3a**.

FIG. **5c** illustrates cross section **560** of ESD device **500** taken at line **501** (FIG. **5a**). $N+$ cathode regions **306**, $p+$ trigger contact regions **214** and optional $p+$ substrate ring **116** are shown disposed in p -wells **512**, and $p+$ anodes **510** are shown disposed in n -well **508**. In the depicted embodiment, p -wells **104** and n -well **308** reside in p -type substrate **102**, however, in alternative embodiments of the present invention, other types of substrates, such as SOI, EPI, or n -type can be used. Silicide regions **111** and contacts (now shown) are provided as described hereinabove with respect to FIGS. **2c** and **2d**. Processing of device **400** (FIG. **5a**) also proceeds as described hereinabove with respect to FIGS. **2a-2d** using similar implants and mask steps for $p+$ and $n+$ regions.

While this invention has been described with reference to illustrative embodiments, this description is not intended to be construed in a limiting sense. Various modifications and combinations of the illustrative embodiments, as well as other embodiments of the invention, will be apparent to persons skilled in the art upon reference to the description. It is therefore intended that the appended claims encompass any such modifications or embodiments.

What is claimed is:

1. A method of operating a semiconductor device, the method comprising:

providing a protection device at a protected node, the protected node being coupled to circuitry in a semiconductor substrate, wherein the protected node is coupled to a first node of an ESD device, the ESD device comprising an ESD device region disposed within a semiconductor body;

a plurality of first device regions of a first conductivity type disposed on a second device region of a second conductivity type, the second conductivity type opposite the first conductivity type, wherein the second device region is disposed within the ESD region;

a plurality of third device regions disposed on the second device region, wherein

the third device regions comprise a sub-region of the first conductivity type and a sub-region of the second conductivity type, and

the plurality of first device regions and third device regions are distributed on the second device region such that third device regions are not directly adjacent to each other;

a fourth device region of the first conductivity type adjacent to the second device region, the fourth device region disposed within the ESD region; and

a fifth device region of the second conductivity type disposed within the fourth device region, wherein the first device regions; the sub-regions of the first conductivity type of the third device region, the second device region, the fourth device region and the fifth device region comprise a silicon controlled rectifier (SCR), and the first node is coupled to the first device regions and the sub-regions of the first conductivity type; and

protecting the circuitry from a high voltage, wherein when the high voltage reaches a level that is greater than an operating level, the protection circuitry will cause a current to flow from a trigger device coupled to the sub-region of the second conductivity type, wherein when the current from the trigger device flows into the sub-region of the second conductivity type, the ESD device latches, causing a high current to flow from the first node to the fifth device region.

2. The method of claim **1**, wherein the trigger device comprises a diode.

3. The method of claim **1**, wherein the trigger device comprises a plurality of diodes coupled in series.

4. The method of claim **1**, wherein the first conductivity type is p -type and the second conductivity type is n -type;

the first device regions and the sub-regions of the first conductivity type comprise an anode; and the fifth device region comprises a cathode.

5. The method of claim **4**, wherein the second device region comprises an n -well.

6. The method of claim **1**, wherein the ESD device further comprises a substrate connection of the first conductivity type at a perimeter of the ESD device region.

7. The method of claim **1**, wherein the first conductivity type is n -type and the second conductivity type is p -type;

the first device regions and the sub-regions of the first conductivity type comprises a cathode; and the fifth device region comprises an anode.

8. The method of claim **7**, wherein the fourth device region comprises an n -well.

9. The method of claim **1**, wherein a distance between adjacent first device regions is between about 10nm and about $10\ \mu\text{m}$; and

a distance between a first device region and an adjacent third device region is between about 10nm and about $10\ \mu\text{m}$.

10. The method of claim **1**, wherein an area of each first device region is greater than an area of each sub-region of the first conductivity type in the second device region.

* * * * *